OFFICE OF RESEARCH & DEVELOPMENT

2012 R&D REVIEW

Vehicle Track Interaction (VTI) Research to Support Derailment Investigations

U.S. Department of Transportation
Federal Railroad Administration

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Program Area & Risk Matrix

Vehicle Track Interaction (VTI) Research to Support Derailment Investigations

Program Areas \ Risk Factors	Trespass	Grade Crossing	Derailment	Train Collision	All Other Safety Hazards
Railroad Systems Issues					
Human Factors					
Track & Structures			X		
Track & Train Interaction			X		
Facilities & Equipment					
Rolling Stock & Components			X		
Hazardous Materials					
Train Occupant Protection					
Train Control & Communications					
Grade Crossings & Trespass					

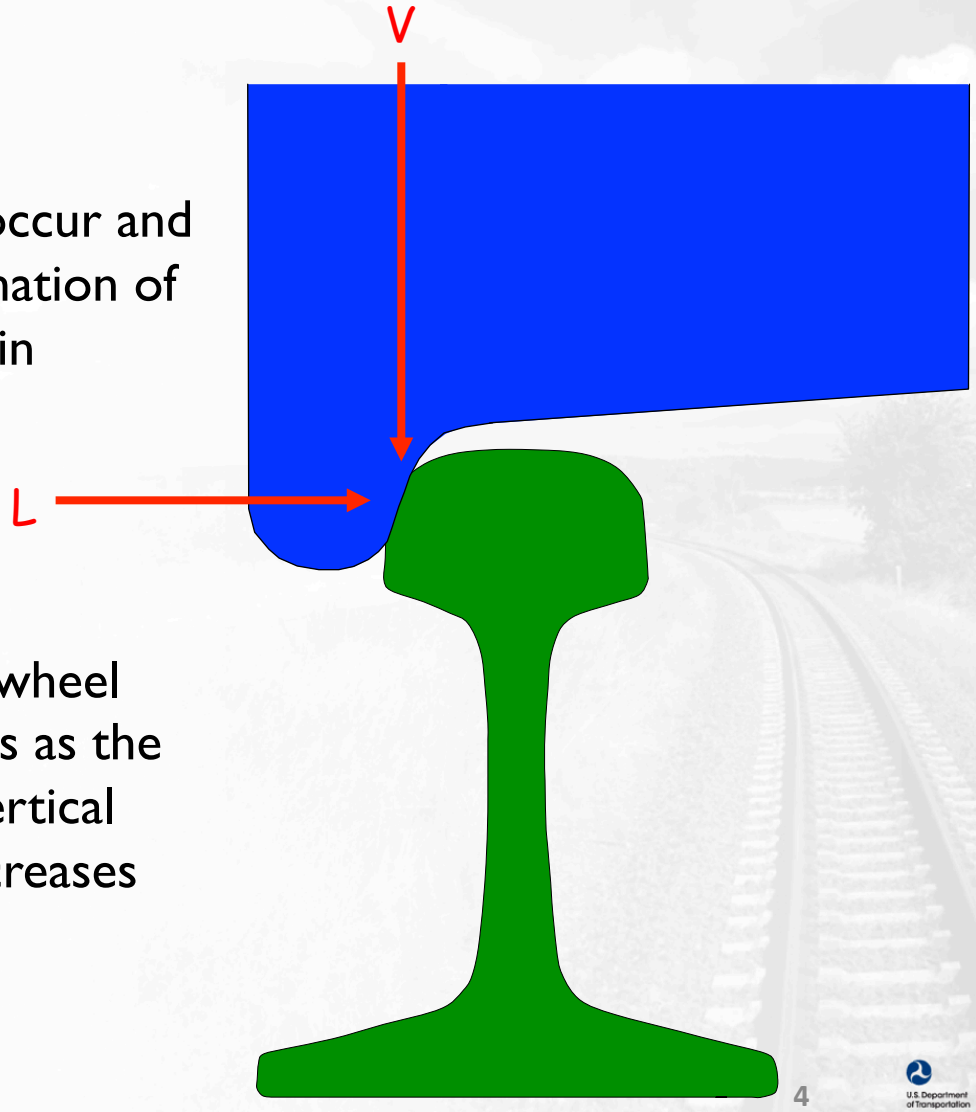
Outline

- Slow-speed wheel climb derailments
- Truck equalization standard
- Curving performance standard
- Characterization of spring behavior
- Vehicle-track simulation software workshop

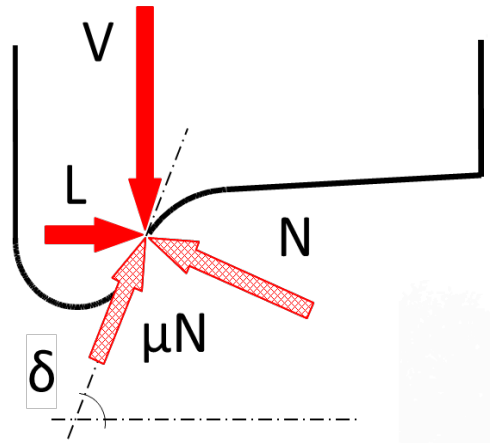
Slow-Speed Wheel Climb Derailments

- Slow-speed wheel climb derailments continue to occur and are often due to a combination of factors (Vehicle, Track, Train Handling)

- The risk of a slow-speed wheel climb derailment increases as the ratio of the Lateral and Vertical wheel/rail forces (L/V) increases

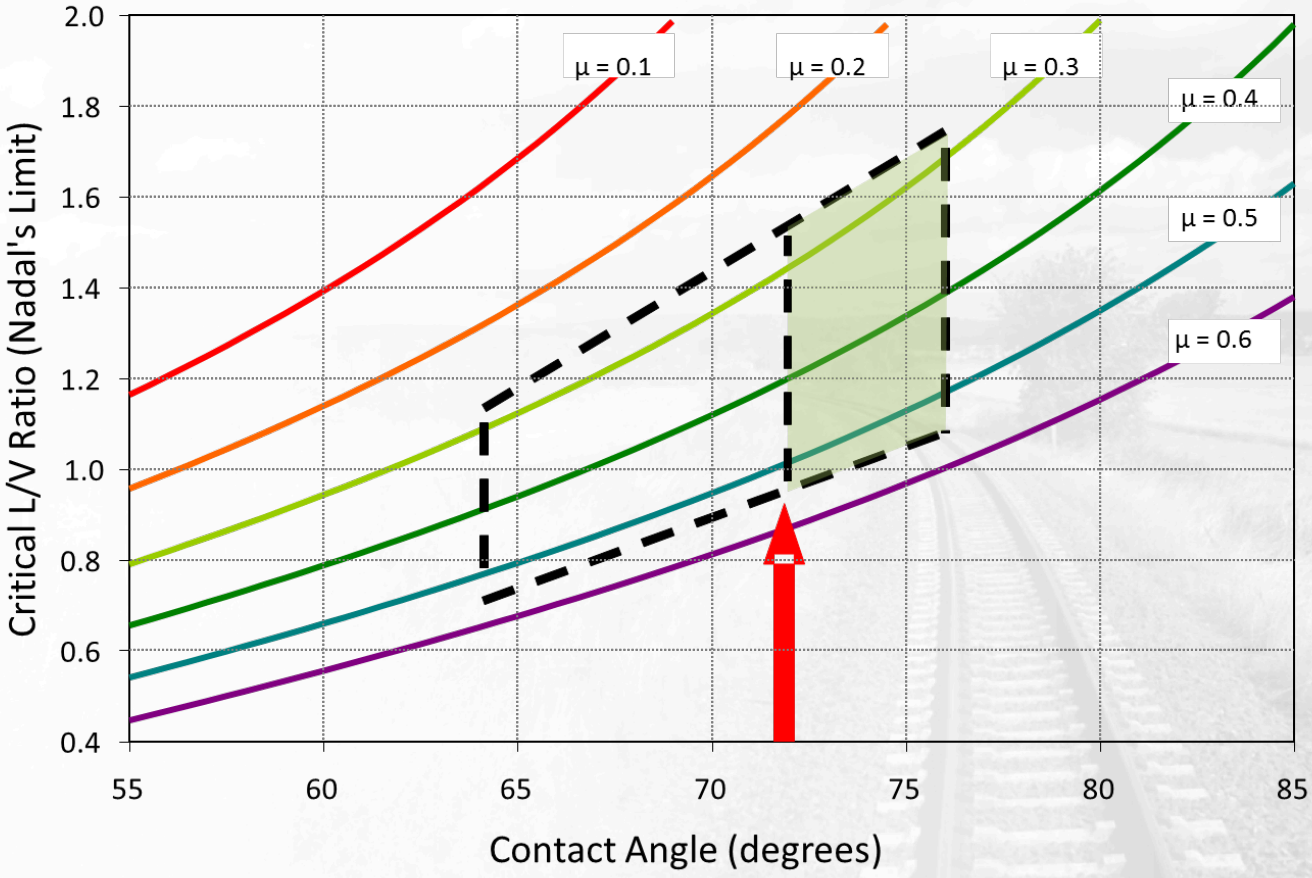


Criteria for Safety Against Derailment: Nadal's Limit



$$\left(\frac{L}{V}\right)_{crit} = \frac{\tan\delta - \mu}{1 + \mu\tan\delta}$$

Nadal's Limit



Slow-Speed Wheel Climb Derailments

Large L/V can be produced by:

High Lateral Force*

- Track Geometry Irregularities
- Vehicle Not Maintained to Specifications
- Wheel/Rail Contact Condition
- Cant Deficiency
- Truck Turning Resistance
- High degree Curve
- Wheel/Rail Friction
- Train Handling

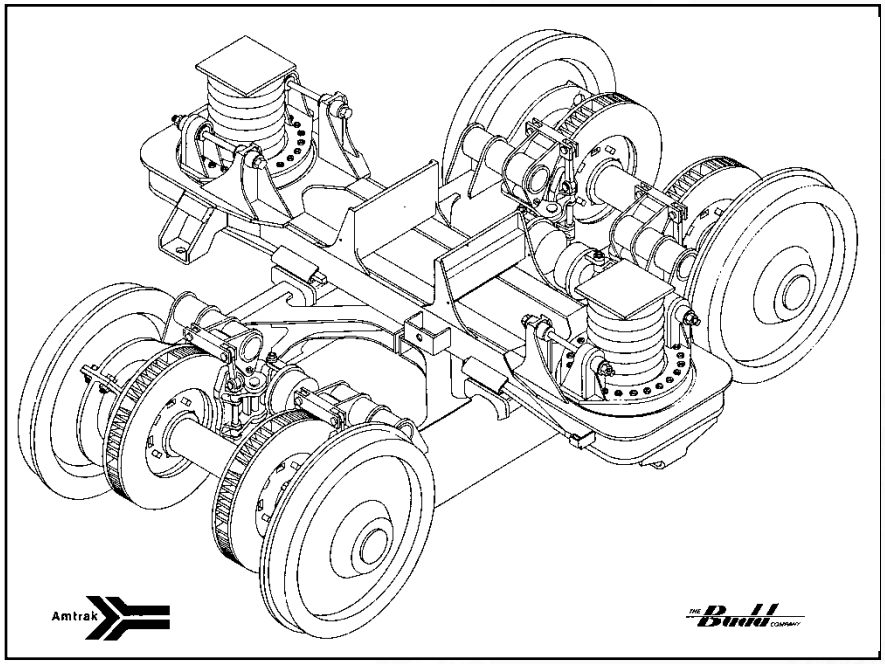
Low Vertical Force*

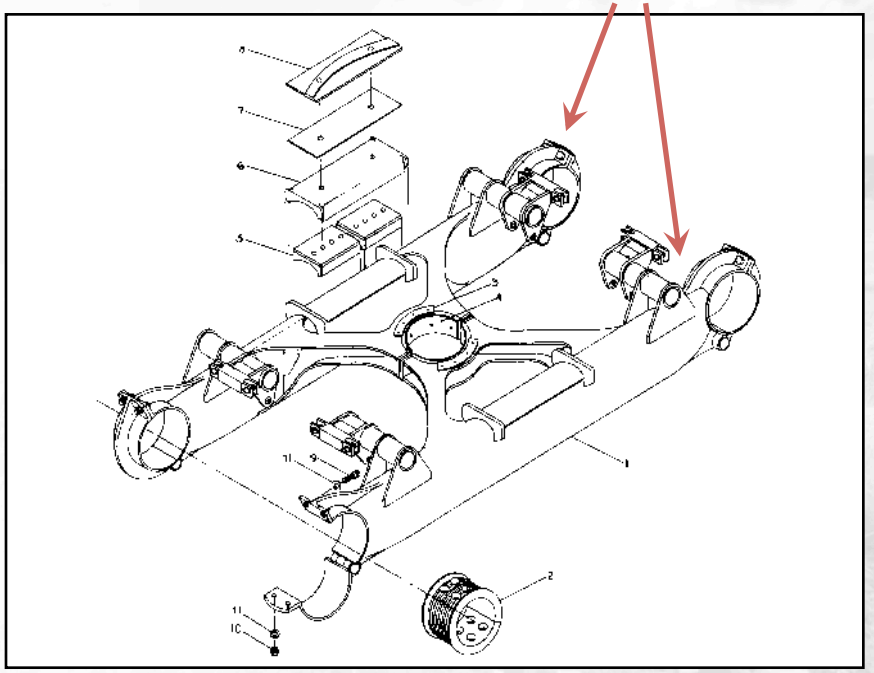
- Track Geometry Irregularities
- Vehicle Not Maintained to Specifications
- Wheel/Rail Contact Condition
- Cant Deficiency (Low V on Low Rail)
- Poor Truck Equalization

**Partial Lists*

Importance of Truck Equalization

- Equalization capability required to negotiate crosslevel or short warp without significant wheel unloading
- Various Truck Arrangements (Split Frame, Equalizer Beam, etc.) are used to Assure Equalization.





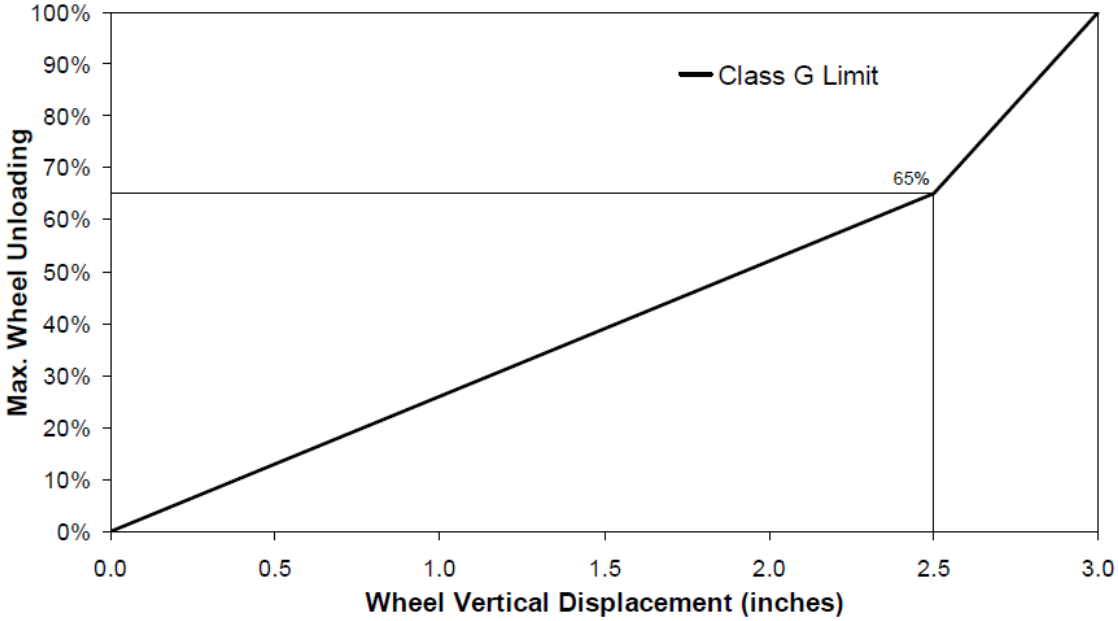
Pioneer III Truck Design by Budd

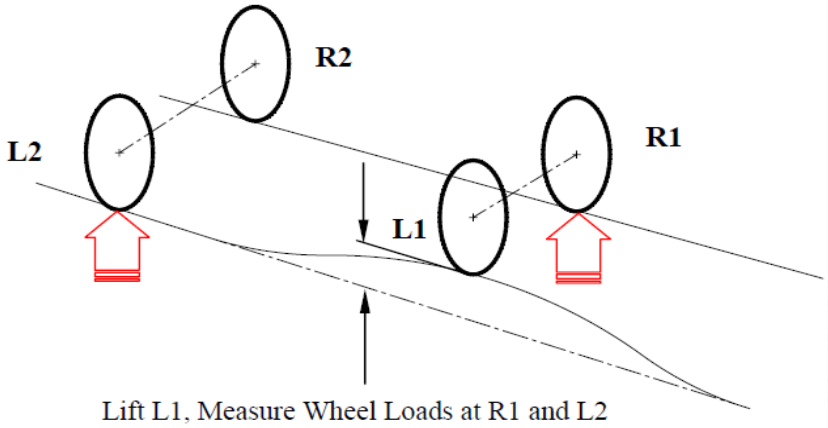
Warp Limits

49 CFR §213.63 Track Surface: The difference in crosslevel between any two points less than 62 feet apart may not be more than

Class	Max Passenger Speed (mph)	Max Freight Speed (mph)	62 foot warp
1	15	10	3
2	30	25	2.25
3	60	40	2
4	80	60	1.75
5	90	80	1.5

APTA SS-M-014-06 Standard for Wheel Load Equalization of Passenger Railroad Rolling Stock

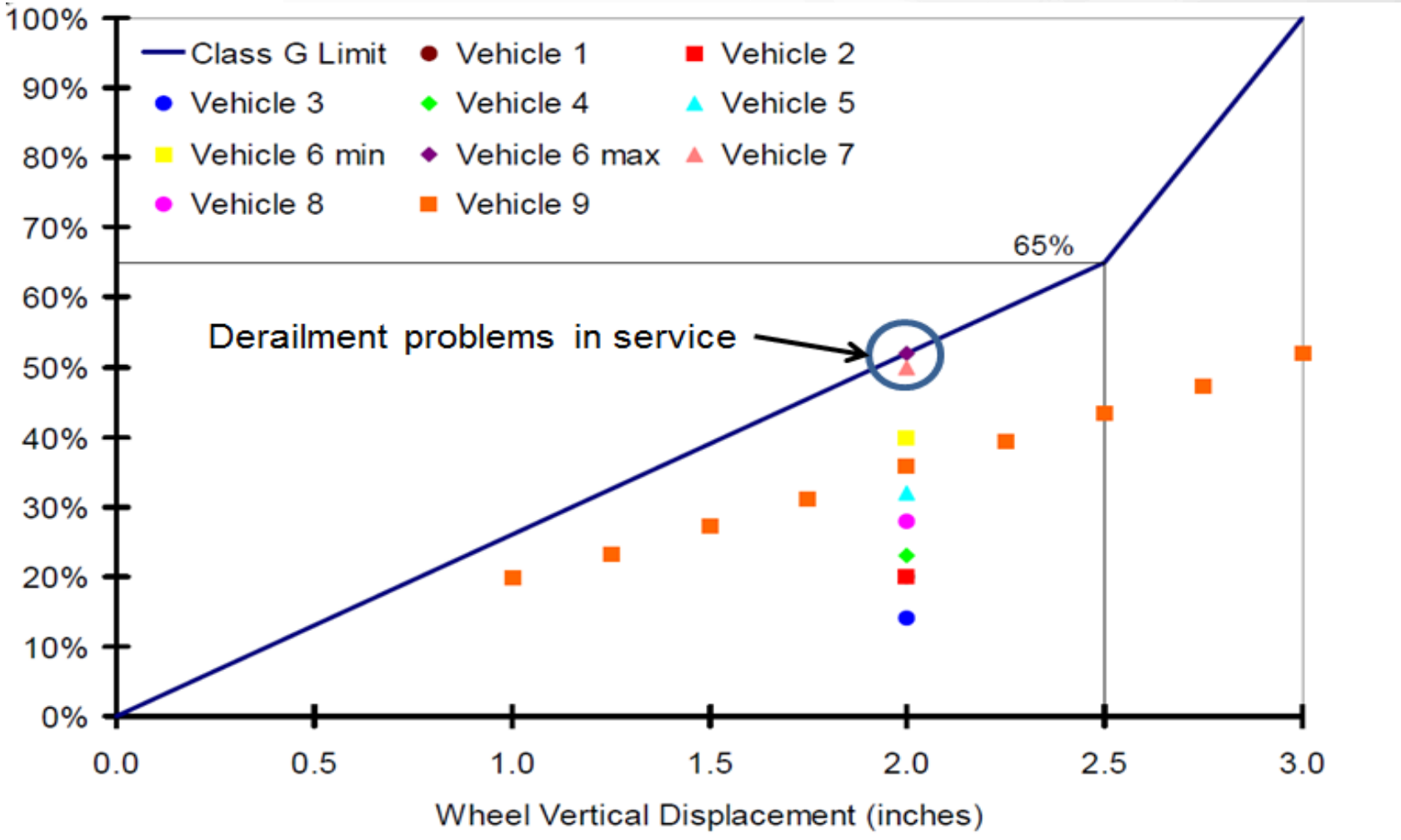




Lift L1, Measure Wheel Loads at R1 and L2

Wheel Lift	Max Unloading (%)
1	26
2	52
2.5	65
3	100

APTA SS-M-014-06 Standard for Wheel Load Equalization of Passenger Railroad Rolling Stock



New Jersey Transit Multi-Level Slow Speed Derailments

- New Jersey Transit (NJT) operates a fleet of 329 Bombardier Multi-Level vehicles
- Operates on both NJT and Amtrak tracks
- Critical to providing commuter service to New York Penn Station
- Put into service between 2006 and 2008
- Involved in eight derailments negotiating
- High curvature special trackwork at speeds below 15 mph
- Two additional derailments occurred during cusp track testing.

Multilevel Cab Car

- No Derailments occurred during the first 3 years of service.
- Until that time, the equipment never traversed over the derailment locations.
- At the time of the first derailment, 205 of the 329 vehicles ordered were in service.

NJT Multi-Level Slow Speed Derailments

Dates and Locations of the 8 Multilevel Derailments:

1. June 4 2010 - Bay Head Yard
2. June 10 2010 - Drill Move - Hoboken
3. August 29 2010 - Drill Move - Hoboken
4. August 30 2010 - Drill Move – Hoboken
5. December 5 2010 - Summit
6. July 23 2011 – Hoboken
7. August 9 2011 – PSNY
8. September 25 2011 – Hoboken

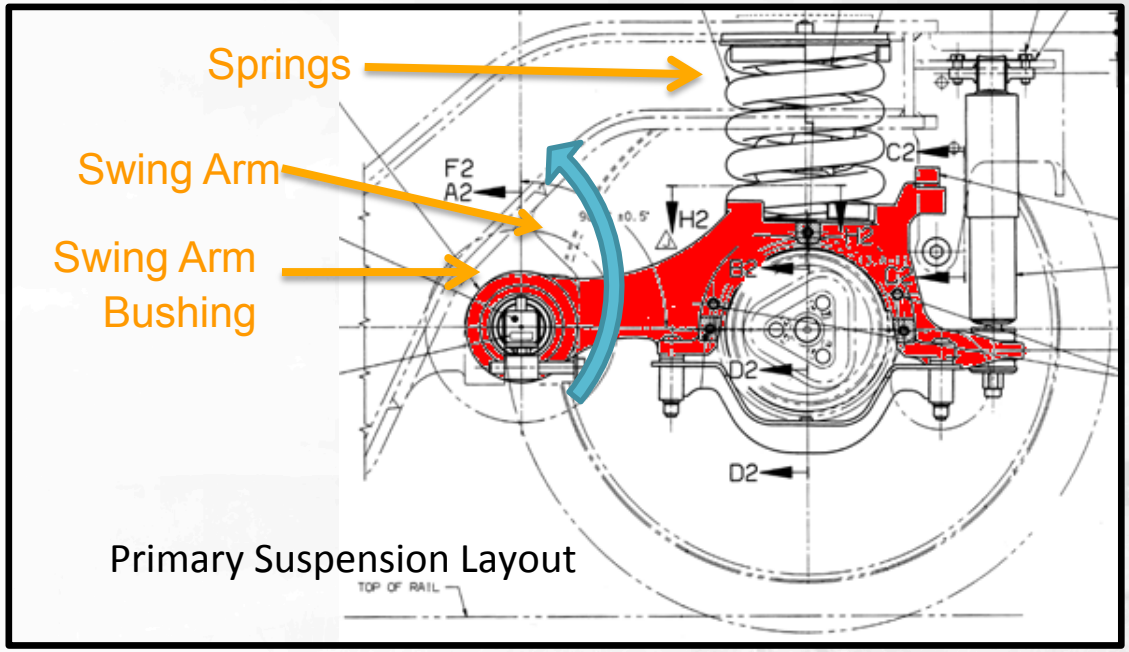
- September 30 2011 – Test Train – MMC Yard
- December 22 2011 – Test Train – MMC Yard

NJT Multi-Level Slow Speed Derailments

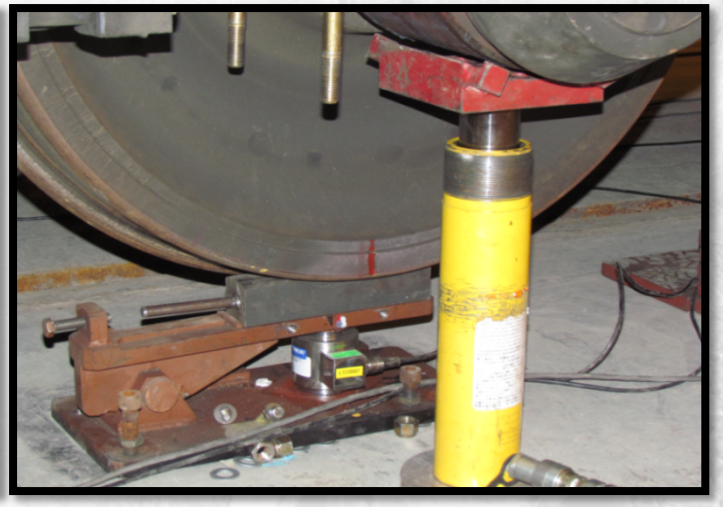
Findings from Investigation

1. Wheel unloading was a major factor in the derailments
   - Static wheel load variation (unloading >10%); and
   - Unloading resulting from "stiff" suspension on warped track - truck equalization

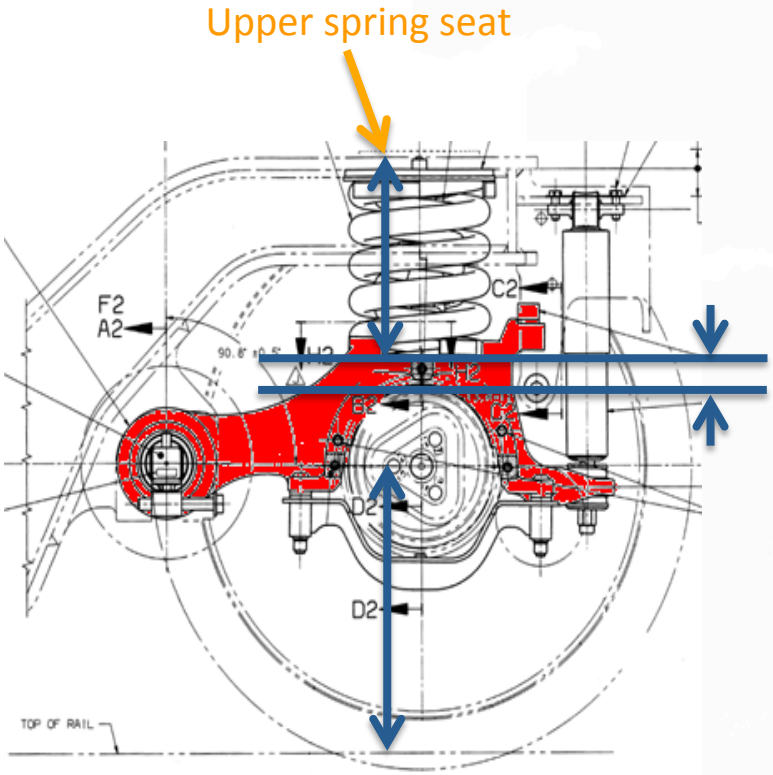
2. Deficiencies with primary suspension springs contributed to wheel unloading
   - Spring height; and
   - Spring stiffness

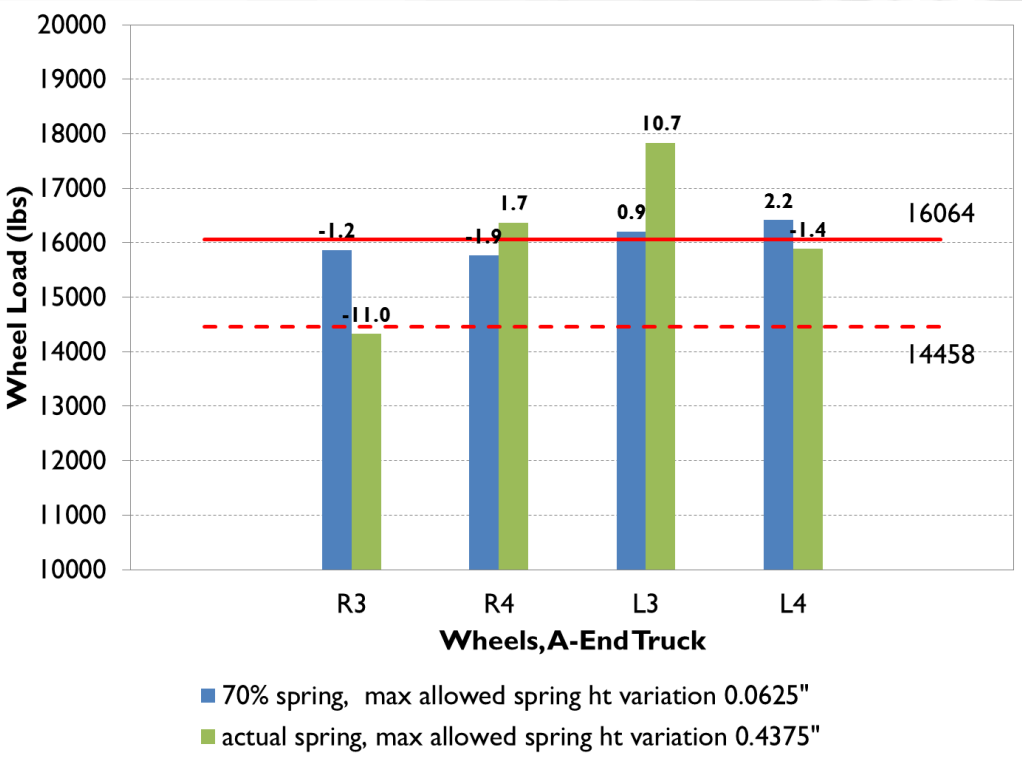


Primary Suspension Layout



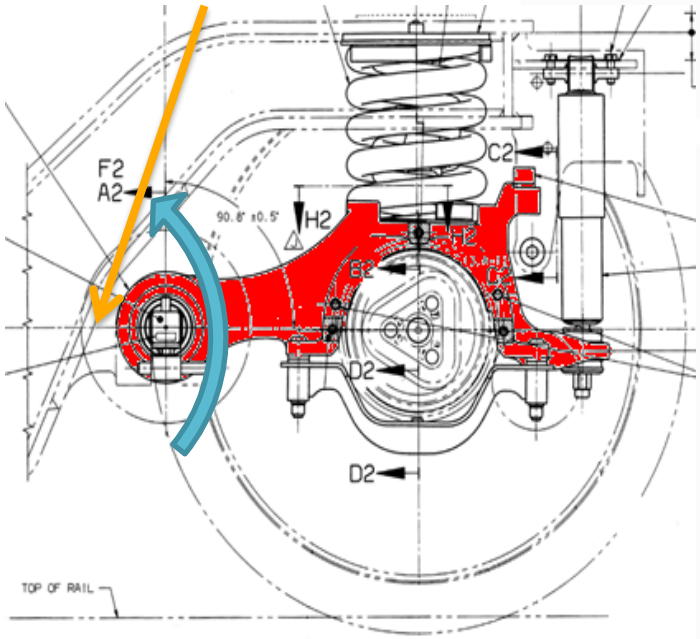
NJT Multi-Level Primary Suspension Springs: Impact on Static Performance

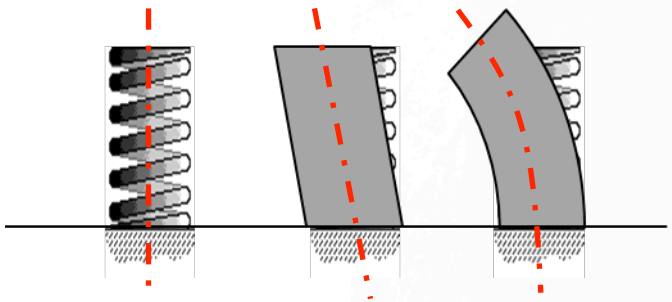


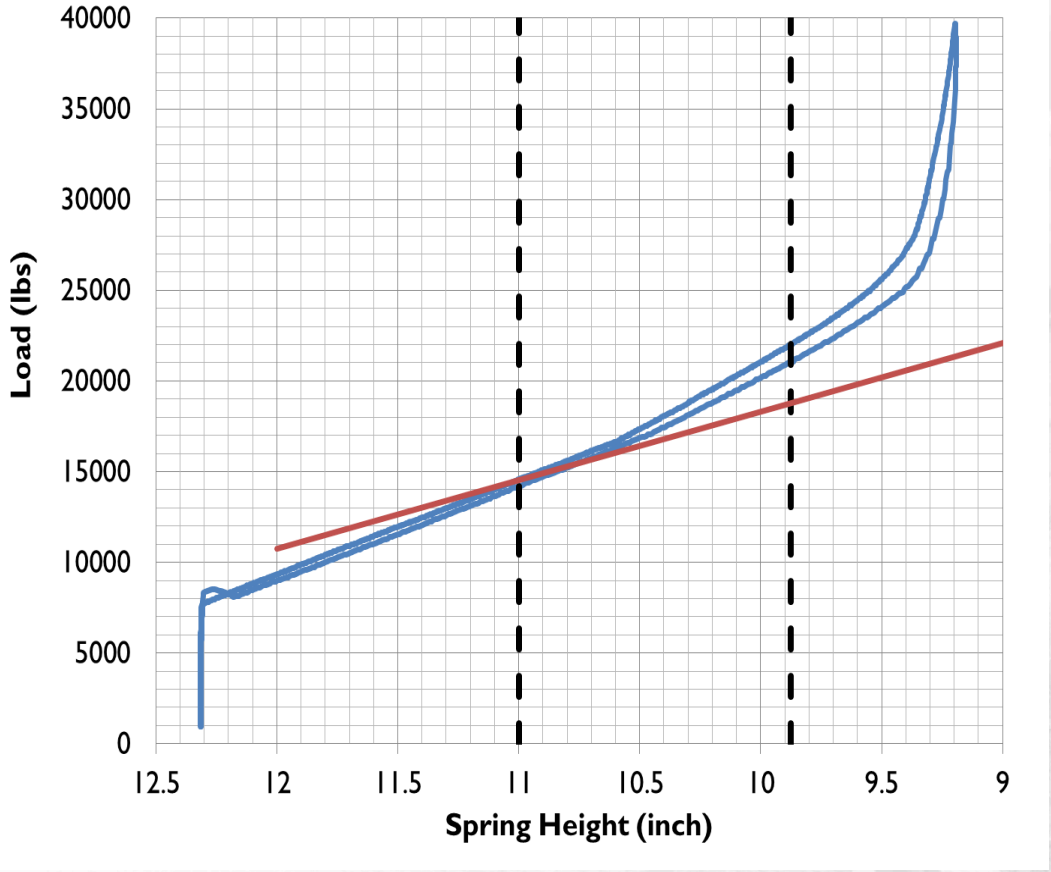


NJT Multi-Level-Primary Suspension Springs: Impact on Dynamic Performance

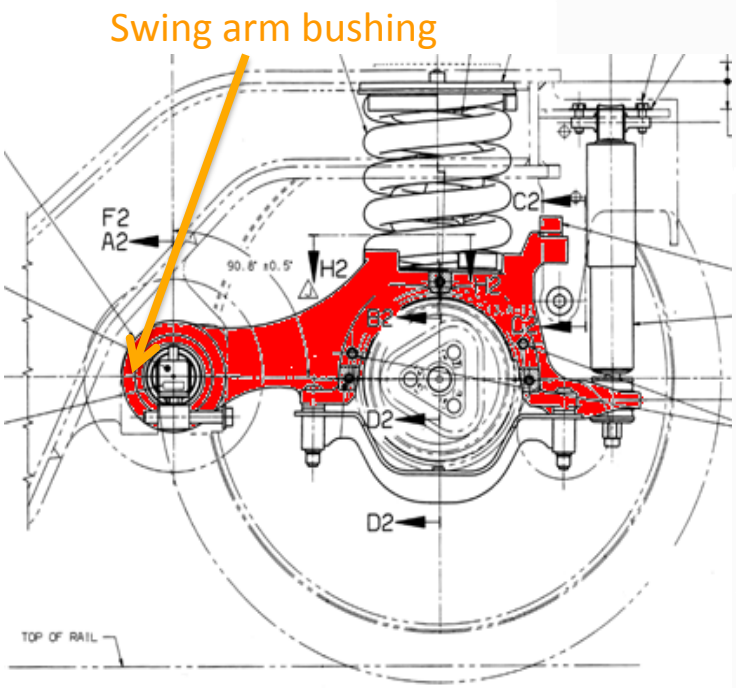
Swing arm bushing

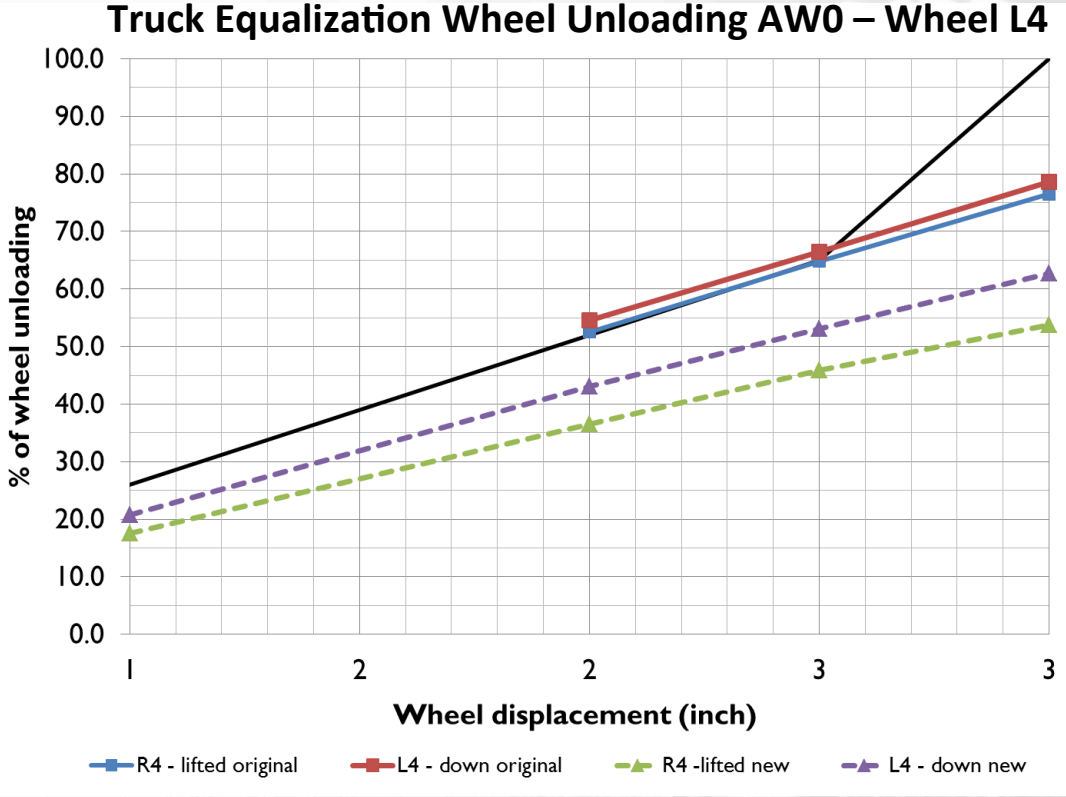






NJT Multi-Level-Primary Suspension Springs: Impact on Dynamic Performance

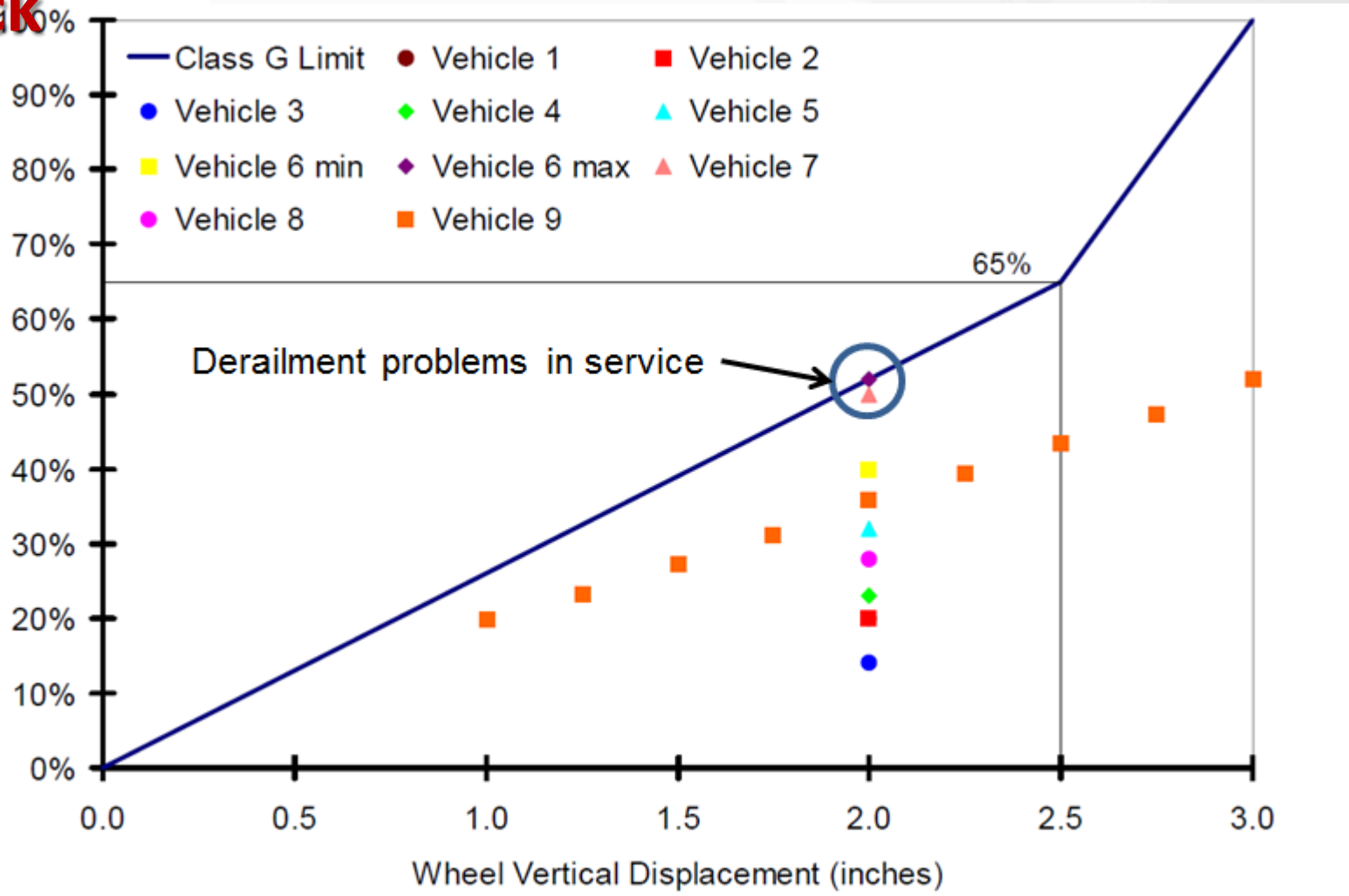




Related Ongoing R&D Tasks

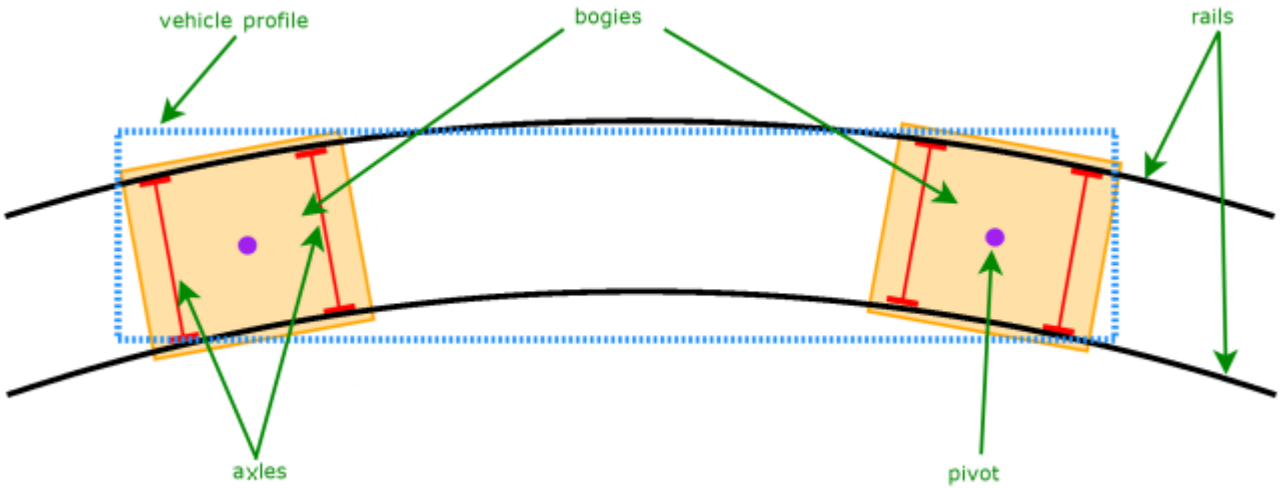
- Revisit track geometry limits for track classes 1-5 for high speed equipment
- Revisit American Public Transportation Association (ATPA) Standard for Wheel Load Equalization
- Development of standard for curving performance
- Spring characterization project: To better understand the behavior and modeling of springs
- Vehicle-Track Simulation Software Workshop: To better understand and improve the capabilities of modeling tools for derailment investigation, etc.

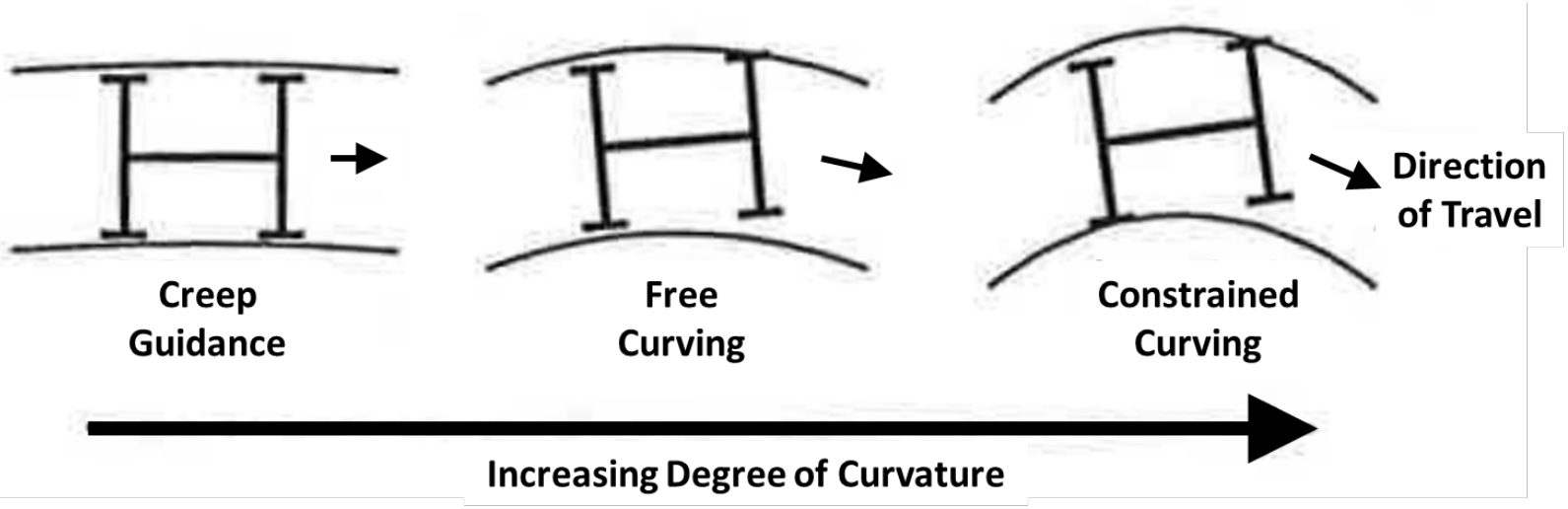
APTA SS-M-014-06 Standard for Wheel Load Equalization of Passenger Railroad Rolling Stock



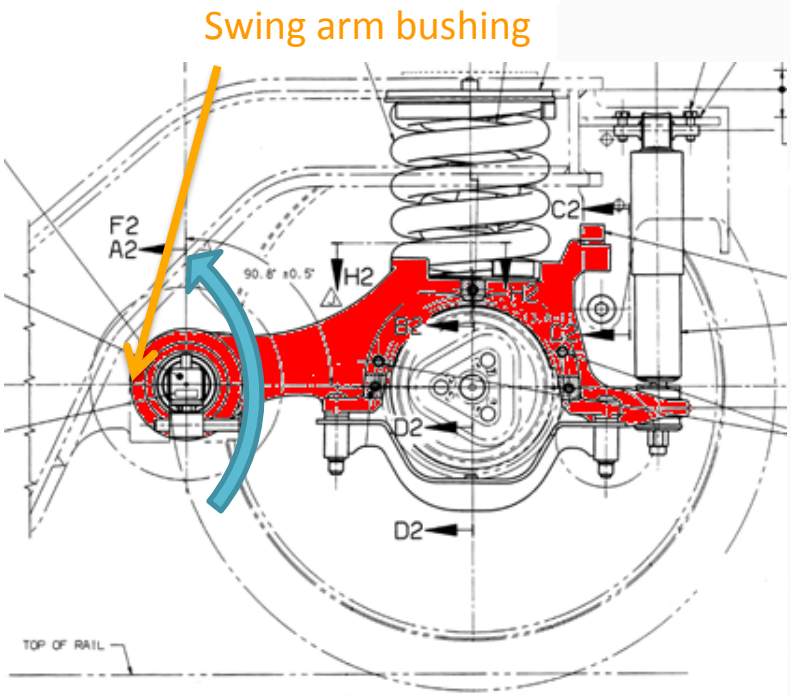
New Standard on Curving Performance

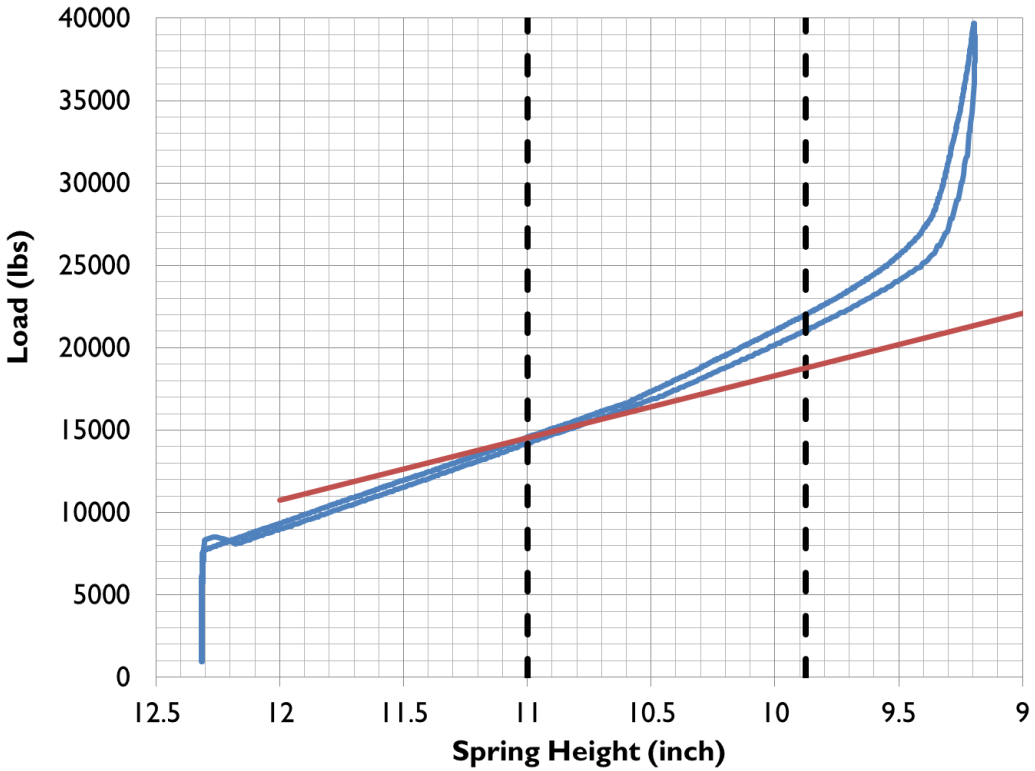
Passing the APTA truck equalization test is good, but not necessarily sufficient.

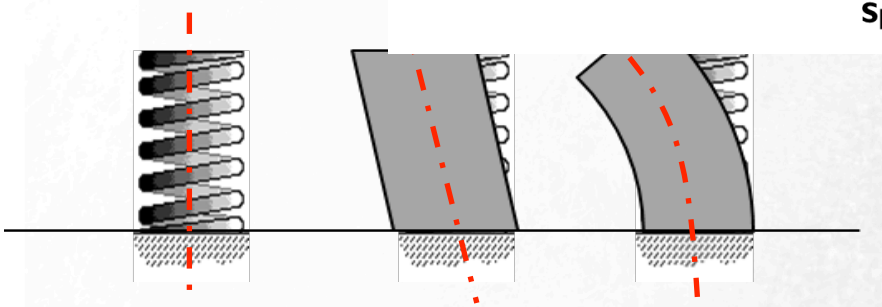




NJT Multi-Level-Primary Suspension Springs: Impact on Dynamic Performance

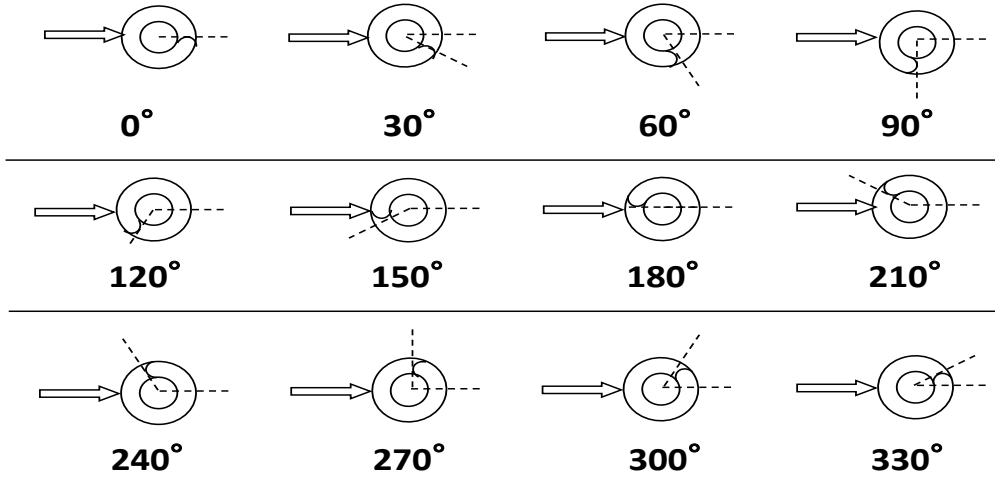


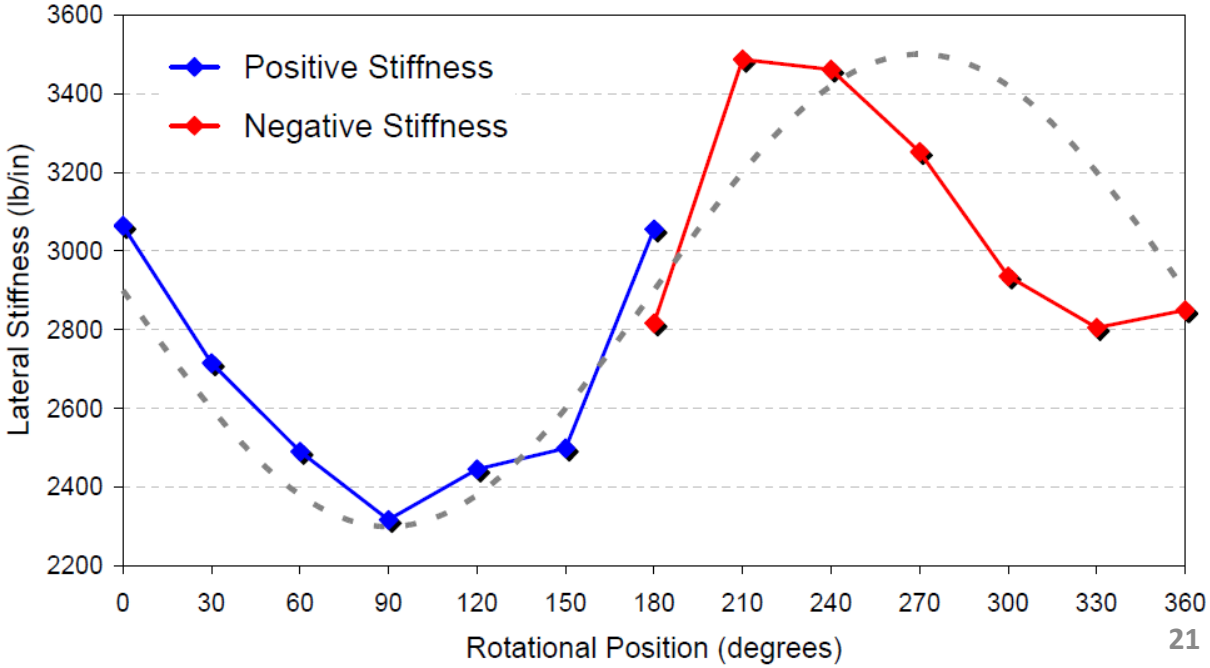




Characterization of Coil Springs

Lateral (shear) stiffness of spring dependent on orientation

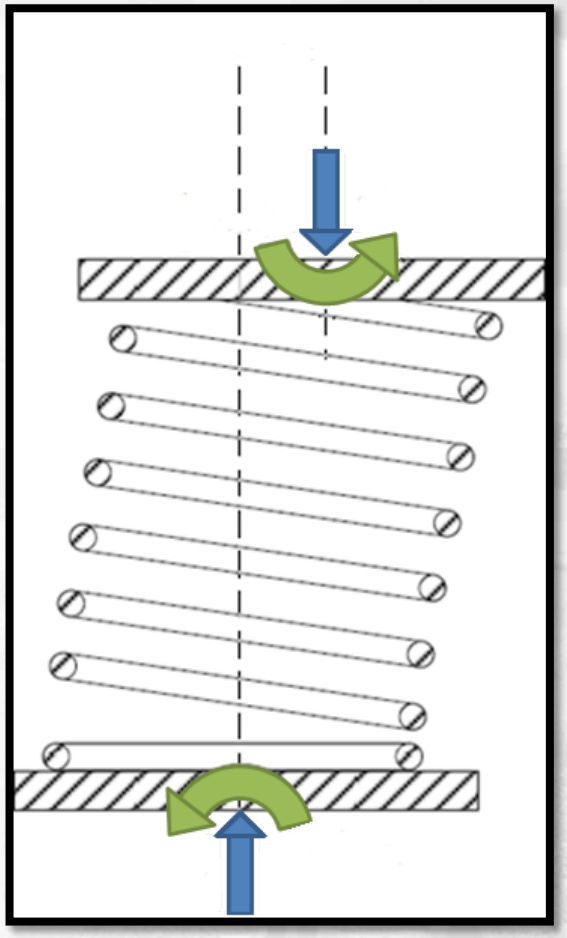




Vehicle-Track Simulation Software Workshop

Simulation packages are available commercially that can be used for a number of requirements including:

- Derailment investigation
- Rule making activities
- Qualification
- Evaluation of vehicle parameters
- Defining loads to be used in other studies



Codes lack certain capabilities that are needed to address some of the modeling requirements above.

- Some codes have some features, while no code appears to have all features.

The goal of this modeling workshop is to assess and develop the state-of-the art of vehicle-track simulation software packages.

- Issues to be considered are development of model capabilities, how to input of parameters into the computer model, model validation.